Fourth Semi-Annual Progress Report for the REASoN Project Entitled

"Border Security Decision Support System
Driven by Remotely Sensed Data Inputs"

April - September 2005

Executive Summary

High Resolution Imagery

The REASoN project team acquired LIDAR data along a portion of the U.S. – Mexico Border in conjunction with a project initiated by a consortium of San Diego government agencies. LIDAR and matching high resolution CIR imagery from Bell Valley westward to Marron Valley along the San Diego County – Mexico Border were collected. LIDAR DEM and imagery products were collected and processed by Merrick, Inc. of Denver, CO.

Early in the reporting period, the U.S. Border Patrol expressed an immediate interest in collecting a full anniversary date set of six inch (0.15 m) resolution CIR photography for the entire length of the San Diego County portion of the U.S./Mexico border. SDSU coordinated the collection, and added selected frames to be acquired at 1 ft (0.3 m) resolution to the mission for additional change detection analyses. By August, all aerial imagery identified as part of an anniversary set of six inch (0.15 m) high resolution CIR photography requested by the Border Patrol for the San Diego Sector has been acquired.

The utility of QuickBird panchromatic and pan-sharpened multispectral imagery (0.6 m spatial resolution) for mapping primary trails along the U.S./Mexico border was evaluated with positive results. The USBP is considering Digital Globe QuickBird imagery provided through NGA as a source of border imagery.

REASoN project personnel completed orthorectifying and registering six-inch resolution (0.15 m), color infrared (CIR) aerial photographs acquired on March 15, 2005 for select portions of the San Diego County section of the U.S./Mexico border to support the automated change detection and feature extraction study.

Trail Mapping

Final digital maps of border roads and trails within 8 km (5 miles) of the border created using the 0.3 m (1 ft) imagery were provided the U.S. Border patrol. These road and trail maps represent the first major extension of migrant and smuggler trails beyond the immediate border zone anywhere is the U.S. Trail mapping in the areas covered by the 0.3 m resolution image mosaics documented a staggering 7250 km (4500 miles) of smuggler trails. The maps reveal very enlightening patterns of cross border trails.

During late May, the REASoN Project Team performed a field reconnaissance along the border to evaluate the presence or absence of trail features mapped during the change detection studies.

Semi-automated Trail Baseline Mapping

The project team performed a semi-automated change detection on orthorectified image pairs using the May 2004 and March 2005 multi-temporal color infrared imagery. Analysts identified land cover changes allowing detection of new and abandoned smuggler trails.

In a related part of the analysis, a test of the image-to-image registration was conducted that demonstrated image to image registration with errors at any location in the scene limited to between 0.15 m (0.5 ft) to 0.3 m (1.0 ft). Accurate registration is critical to automated change detection. Feature Analyst and eCognition software are being investigated as semi-automated trail extraction tools.

Moderate Resolution Imagery

The study to assess the impact of trail development on vegetation condition since the implementation of Operation Gatekeeper using the normalized difference vegetation index (NDVI) from TM/ETM+ imagery revealed that fire history and the post-fire stage of vegetation recovery were the dominant causes of temporal differences in the NDVI. Additional analysis revealed that the areas of greatest change appear to be related to urban expansion and rural residential development. The Vegetation Analysis component of the project is also contributing data derived from the Landsat TM series as input to GIS models.

Aircraft Radar Fade Analysis

Radar fade report data from 2000 through 2004 containing over 500 fade reports were analyzed. Analysis of initial detection locations and corresponding fade locations identified systematic patterns in the data and show fade clusters corresponding to clandestine airfields in northern Baja California, Mexico.

Results from the fade analyses were briefed to the USBP and the intelligence staff at the Air Marine Operations Center. Several geospatial analysis methods were introduced to AMOC analysts who will employ them in future radar fade data analyses.

The clandestine airfield study indicates that isolated fields, remote dirt roads and cleared hillside meadows appear to be frequently used as landing sites while the use of traditional, well prepared airfields is rare. Continued analysis of radar fade data shows promise for improving drug interdiction activities.

Clandestine Airfield Modeling and Analysis

Preliminary landing field suitability model logic development has been completed. Several site suitability models were tested using existing data sets to determine optimal processing methods. Initial landing field prediction models suggested potential locations in eastern San Diego county and western Imperial county.

Demographics

During late May, the project team met with Senior Border Patrol staff to review current analyses results, discuss current and future SDSS needs, and prioritize future research and analysis objectives. The Border Patrol expressed strong interest in the results to date and confirmed that the project team had the correct focus in terms of the analysis objectives and products being produced.

Significant progress continues to be made in developing a statistical model for analyzing the economic, social and political climate and how these variables 'push' migrants toward the United States. The project team completed identifying the Border Patrol sectors at which people from each municipio in Mexico were arrested. Identification of such patterns allows our analysis to determine the likelihood of migrating to a specific border sector as a function of municipio of origin.

The project team completed compiling municipio of origin statistics from the ENFORCE 2003-2004 (San Diego Sector) data set. This is a key accomplishment for analysis of the location of origin for illegal immigrants from Mexico.

The project team also made major progress in extracting demographic and economic data from the Instituto Nacional de Estadistica, Geografia e Informatica (INEGI) website for linking to U.S. border apprehensions data. The linking of the characteristics of migrants apprehended at the border with information from their state and/or municipios of origin in Mexico allows identification of factors which induce migration to the U.S.

The demographics project team completed a data matrix at the state level (32 states) and is nearly finished with the complete data matrix for 26,600 municipios.

WEB-Based Wireless GIS

The Web-based GIS and Wireless GIS Communications project team is coordinating with the Supercomputer’s GEON project team to demonstrate data sharing. Such sharing techniques are essential to homeland security data warehousing and retrieval of real time data services (i.e. weather, traffic, damage assessments, imagery, etc.).

Dr. Tsou presented a paper at the ESRI International User Conference on July 28 describing an Internet-based Spatial Decision Support System (SDSS) using Real-Time Wireless Mobile GIS devices

Data warehousing and metadata integration research continued with the research team finishing the design of SDSU Department GIS/RS data portal containing over 360 metadata records in GIS and RS.

The research team customized ArcIMS viewers to provide online mapping and analysis functionalities via secured communication channels. Such functionality is necessary for Border Patrol sectors to exchange information or to query information from intelligence processing centers such as the San Diego Sector CCICC. Several viewers examples were created demonstrating key integration capabilities needed in an SDSS.

The wireless/mobile GIS research team completed comparison of the performance between secured Internet communication (HTTPS) versus un-protected Internet communication protocol (HTTP) for Web-based mapping applications.

The project team created sample websites for demonstrating the capability of Web-based mapping for the REASoN project including 3-D imagery.

Dr. Ming Tsou and co-author Dr. Sun from National Taiwan University wrote a paper about using Mobile GIS for Disaster management based on applications derived from the REASoN project. The paper has direct application to Hurricane Katrina's disaster management issues.

One of the major challenges facing the border patrol SDSS is the speed at which law enforcement sensitive data can be transmitted to agents in the field over encrypted communications links. To address this issue, the research team compared the performance between secured Internet communication (HTTPS) versus un-protected Internet communication protocol (HTTP) for Web-based mapping applications.

In September, Dr. Tsou wrote an article about the recent changes in Internet GIS. The paper can be read at the following URL:
http://www.gisdevelopment.net/technology/gis/techgis_002.htm

Spatial Data Mining

Spatial data-mining and algorithm development activities continue using a 1.4 million record ENFORCE data set covering the period of 2003 thru 2004. These analyses continue to identify interesting spatial patterns in smuggling activities and apprehensions.

The Data Mining project team revised the EID analyses including descriptive analysis, origin analysis, event role analysis, density analysis, and hypothesis formulation using improved procedures. They also generated valuable measures of illegal immigration by Mexican state of origin based on quarterly intervals.

The Data Mining and Demographics Analysis Project Teams conducted technical interchange meetings with the San Diego Sector Border Patrol technical staff to identify and transfer analyses results, data mining strategies and analysis algorithms, and to discuss future analysis directions. The Border Patrol has expressed a strong interest in implementing REASoN analysis algorithms as operational tools. Once operationally tested and validated by the San Diego Sector, these tools can be implemented in other Border Patrol sectors around the US.

The REASoN team is exploring Rough Sets methodology for data classification rules. The team is investigating whether Rough Sets might be applicable to the automated discovery of patterns in the apprehension database. The automated pattern discovery may be applicable to operational decision making, especially when real or near-real time data from various sensors are used.
The project team also created several additional predictor datasets to expand a model for predicting geographic patterns of illegal immigration across the border.

Most recently the project team has focused on developing a segmentation of the border into homogeneous segments representing the difficulty of crossing the border by the illegal immigrants.

The project team integrated the Google Earth map service with apprehension data and analysis results. The project team implemented several vector and raster integration modules with the Google Earth map service to display border apprehension data and analysis results enhancing information display and interpretation.

SEEDS

Two REASoN team members attended and participated in the ESIP Federation meeting held on June 14-16, 2005 in San Diego at the Doubletree Hotel Mission Valley at Hazard Center.

Dr. Tsou will attend the 4th ESDSWG meeting on October 25, 26, and 27 in Washington D.C.

Dr. Tsou continues to participate in the weekly SPG staff telecom meeting and monthly SPG all members meeting, and the co-chair meeting each month.

Other Significant REASoN Activities

An executive summary briefing was presented to Chief Darryl Griffen and members of his senior staff on the 17th of August, 2005. The two hour briefing to Chief Darryl Griffen described project activities and the results of the project research areas including: high resolution imagery analyses, moderate resolution imagery analyses, GIS modeling, demographic analyses, data mining, wireless GIS, mobile GIS, and data visualization. The briefing consisted of over 175 briefing slides and required two-hours to present.

Dr. Douglas Stow introduced the NASA REASoN program and described the research activities for the high resolution and moderate resolution imagery research tasks. Mr. John Kaiser followed with a description and summary of GIS modeling tasks. Dr. Ming Tsou presented project activities and results from the wireless mobile and web-based GIS integrations tasks. Dr. John Weeks presented the research and results from the apprehension demographics analyses and the apprehension data mining research. The briefing concluded with Mr. Kaiser presenting data and information visualization methods emphasizing satellite imagery and 3D fly-through techniques.

Chief Griffen and his staff asked numerous questions and provided guidance on issues of immediate and long–term importance to the Border Patrol. The Chief expressed his strong and continuing support for the project and his appreciation to NASA and SDSU for their support to the Homeland Security Mission. The Chief reaffirmed the importance of the REASoN research activities to his sector and the whole of the Border Patrol. He indicated that many of the results of the REASoN research initiatives are establishing standards and models for implementation throughout the whole of the Border Patrol. The Chief requested SDSU support in briefing REASoN project results to the Chief of the Border Patrol in Washington, D.C.

INTRODUCTION

The objective of the Border Security Decision Support System project is to extract information and knowledge content from remotely sensed imagery and geospatial data and assimilate such information into a spatial decision support system (SDSS) for use by border security agencies in securing U.S. borders to prevent and reduce America's vulnerability to terrorism and smugglers. A team of Homeland Security, state and local law enforcement and resource agencies, researchers from San Diego State University (SDSU), and remote sensing technology companies are collaborating on this project. The data products, GIS models, and decision support algorithms will be validated and integrated into operations in the United State Border Patrol (USBP) San Diego Sector by the end of the study and will serve as a prototype for the other 20 USBP sectors within the United States.

Following the events of September 11, 2001, the United States Border Patrol has been increasingly concerned with enhancing homeland security by minimizing the flow of people or materials across our borders that may facilitate terrorism. The USBP is committed to the utilization of new and advanced technologies for monitoring and enforcement within the border region. In particular, the agency is interested in implementing geo-spatial technologies such as remote sensing, geographic information systems (GISs), global positioning systems (GPSs), and spatial decision support systems (SDSSs) to assist them in better securing our borders. The USBP is dedicated to the implementation of a national border security decision support system that will increase their ability to secure the U.S. border and increase the efficiency, productivity, and safety of agents. Local and state law enforcement and resource agencies are secondary but important partners with the USBP in securing and managing the international border zone. Technology exchange relationships have been established with local, state, and federal agencies such as the San Diego Police Department, San Diego Sheriffs Office, San Diego Association of Governments, California Department of Forestry, and U.S. Forest Service. Information and technology that has been proven to be beneficial to the USBP is directly portable to other local, state, and federal agencies.

The primary objective of this study is to develop data products and information extraction algorithms for the USBP SDSS that will be utilized by all levels of the USBP and collaborating local, state, and federal agencies to tactically and strategically allocate and disseminate personnel and technology resources for securing the international borders of the US. Key data sets and information products of the SDSS are being derived from remote sensing and image processing techniques that have been developed through past NASA sponsored research efforts.

GENERAL STUDY APPROACH

A comprehensive and generalized view of the end-to-end system being developed is portrayed in the flow diagram or graphical “road map” in Figure 1. An important aspect of this system is its hierarchical monitoring subsystem being developed for two border management zones using imagery with differing spatial resolutions. The USBP's deterrent zone extends 4 km either side of the border, while their tactical response zone extends 50 km into the U.S. side of the border. High spatial resolution (0.5 – 5 m) imagery from commercial aircraft and satellite-borne systems is required for the deterrent zone, to detect and monitor features such as trails, tunnels, and structures for facilitating or concealing illegal border crossings. Such imagery also enables law enforcement agents to record locations and provide geographic context for interdictions of smugglers and undocumented immigrants. Moderate resolution imagery from Landsat TM/ETM+ and TERRA ASTER, covering the tactical response zone, enables mapping of potential landing zones for smuggler aircraft and provides vegetation and land cover information for trafficability assessments. TERRA/AQUA MODIS data covering the tactical response zone provides dynamic information on fire fuel flammability (risk to border security agents) and weather-related risks to agents and undocumented immigrants.

These image-derived products are being integrated with thematic layers in GIS-based models to support the SDSS. Mobile communication, web-base GIS, and wireless hand-held computers GPS integration technologies are being developed to link directly to the SDSS enabling data input and resource allocations and enforcement decisions. The same technologies and data bases enable the USBP and cooperating state and local agencies to monitor environmental degradation and fire risk, and to prepare to mobilize for natural and bio-terrorist hazards.

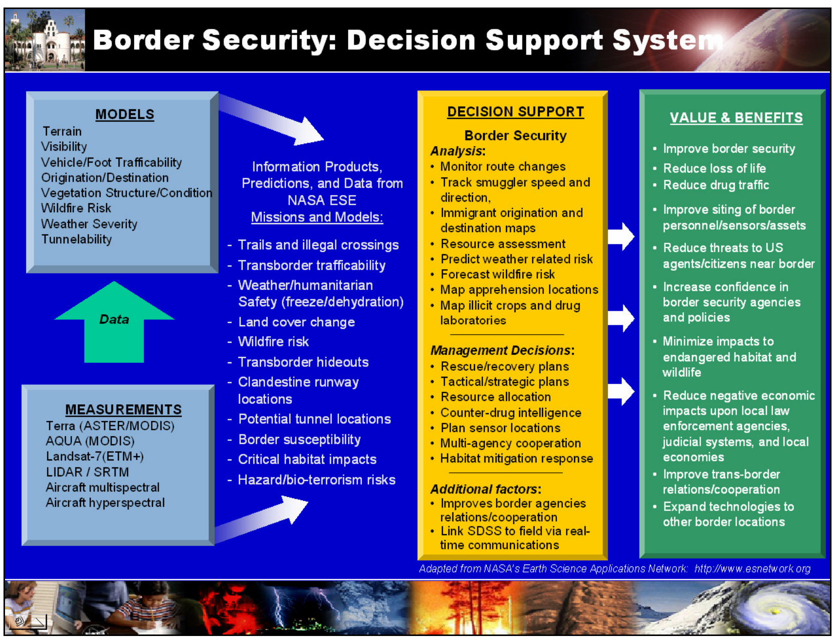


Figure 1. Spatial decision support system flow diagram.

RESEARCH FOCUS AREAS AND TASKS

The research tasks conducted within the Border Security Decision Support System program focus on seven research areas. These focus areas include: high spatial resolution remote sensing, moderate spatial resolution remote sensing, geospatial modeling and analyses, analysis of interdiction demographics, web-based and wireless GIS, spatial decision support analytical tool research and data mining and SEEDS (ESDSWG) participation.

<u>High Spatial Resolution Remote Sensing Focus Area</u>

Supervised by Dr. Douglas Stow.

Low Cost CIR Airborne Digital Imaging Task

This general task pertains to techniques for generating precise image mosaics covering the border tactical zone at very high spatial resolution, several times per year, and for efficient extraction of land surface features of interest to USBP from this imagery. Elements of this general task include evaluation of various sensors and sources of high spatial resolution multispectral image data, geometric and radiometric pre-processing requirements for generating multitemporal data sets having high fidelity, and evaluating interactive and semi-automated approaches for delineating trails and other land surface features associated with smuggling operations.

Task Activities:

<u>Image Acquisition</u>:

Low cost CIR airborne digital imaging

During the six month period between April and September 2005, multiple airborne digital image sets were acquired and processed for the purpose of evaluating the utility of low cost color infrared (CIR) airborne imagery for mapping features and monitoring changes along the U.S/Mexico border. Large format, high spatial resolution (0.15 m and .3 m) CIR aerial photography were acquired in March, July, and August 2005 for selected portions of the San Diego County section of the U.S./Mexico border. These photos were acquired at the same photo positions as the May 2004 image set, a process referred to as "frame center (FC) matching." At the moment of image acquisition, the camera is at the same location in the sky (horizontal and vertical) between the two dates, the terrain distortions are virtually identical in the imagery, and precise registration can be achieved using conventional image registration techniques.

The project team performed a test of the image registration accuracy. A March 2005 photo was orthorectified using the corresponding orthorectified May 2004 image as the registration base. In addition, the same digital elevation model (DEM) used to orthorectify the May 2004 frame was used in the process to orthorectify the March 2005 frame. The image-to-image registration between the multi-date image frames was very good, with misregistration at any location in the scene on the order of 0.15 m (0.5 ft) to 0.3 m (1.0 ft). The precise image-to-image registration makes the imagery highly suitable for detailed change detection analysis. Such a capability is highly desired by the United States Border Patrol.

LIDAR derived elevation data and supporting CIR imagery

During April 2005, SDSU contracted with Merrick, Inc. for the acquisition a high resolution, LIDAR-derived DEM for the border area from Bell Valley westward to Marron Valley along the San Diego County – Mexico Border. This area was selected to support both Border Patrol and SDSU research initiatives. Supporting high resolution CIR imagery is also being provided as part of the LIDAR acquisition. SDSU was able to cost effectively acquire border LIDAR data by participating in a planned LIDAR and aerial photo mission being conducted for a consortium of San Diego government agencies. This acquisition provides both a LIDAR-derived DEM and very accurately positioned CIR imagery (CE90 of 1 m). This product set will facilitate assessment of commercial products for long-term operational monitoring of the border region. By late May, Merrick, Inc. had completed acquisition of the LIDAR and high resolution CIR imagery along the San Diego County – Mexico Border. SDSU was given a target delivery date in August. SDSU received the received delivery of raw and orthorectified CIR imagery in mid-September. SDSU expects delivery of the LIDAR elevation data shortly.

Anniversary date border imagery

In April, the U.S. Border Patrol commissioned and funded the collection of an anniversary set of six inch (0.15 m) resolution CIR photography for the entire extent of the San Diego County section of the U.S./Mexico border. SDSU prepared the flight plan and coordinating with a local aerial photography company throughout May. Initial attempts to acquire imagery were delayed due to poor weather conditions. Sixty percent of the imagery was acquired July 22, 2005. The remaining imagery was acquired on August 17, 2005 after another significant weather delay. Registration of the imagery to baseline May 2004 orthophotos was initiated in September and continues. All images were collected with frame centers matching corresponding photos collected in May 2004. This method of acquisitions is enabling precise image-to-image registration and making the imagery suitable for detailed change detection analysis. Change detection is currently being performed using July 2005 and May 2004 imagery, and results will be presented at "The 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment" in early October, 2005.

ADAR imagery collection

In addition to LIDAR and anniversary imagery collections, digital multispectral imagery was also acquired for high interest study areas along the U.S./Mexico border using an ADAR 5500 airborne camera system owned and operated by the San Diego State University Department of Geography. Twenty frames of 1 m multispectral imagery were acquired with frame centers matching those of an April 9, 2002 acquisition for the Bell Valley area along the border. These multitemporal ADAR 5500 images allow continued assessment of digital multispectral imagery for long term change detection and monitoring of conditions along the border.

Change Detection Analyses:

The use of automated and semi-automated change detection methods are essential to the Border Patrol to reduce the labor intensive elements of this activity enabling routine use of imagery-based change detection along the 2200 mile southern border with Mexico. Following receipt of the newly orthorectified and registered CIR imagery, change detection analyses were conducted to identify the types of detailed changes which can be detected using precisely registered, high resolution multitemporal imagery. The SDSU project team began change detection analysis with precisely registered six inch resolution (0.15 m) color infrared (CIR) aerial photographs acquired during May 2004 and July 2005. Changes were detected by reviewing red waveband overlay composite images, in which the red waveband for the May 2004 images was displayed in blue and green color guns, and the red waveband for July 2005 images were displayed in the red color gun. Using this simple technique, increases in red waveband brightness over time appeared as red, while decreases in red waveband brightness appeared as cyan. The high spatial resolution and precise registration of the multitemporal image pairs enabled detection of change features such as individual shrub growth; individual shrub loss due to fire; vegetation recovery following fire, dirt road widening; off-road vehicle tracks; river channel change and sedimentation; new foot trails; small drainage scouring; individual tree removal; land clearing, and new dirt roads (Figure 2). Many of these change elements are of significant informational value to the Border Patrol.

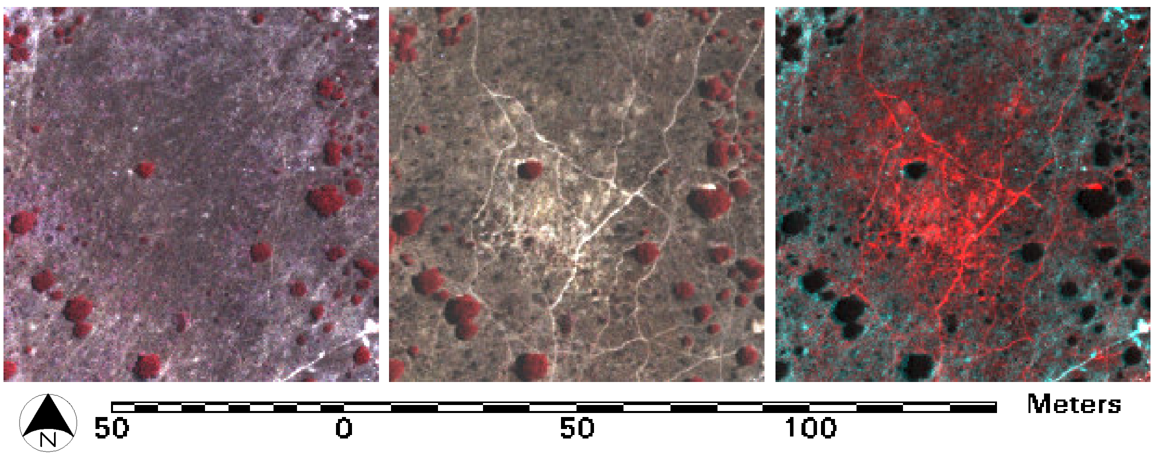


Figure 2. Graphic a. displays May 2004 CIR image with little ground disturbance. Graphic b. displays July 2005 CIR image with ground disturbance. Graphic c. displays disturbed areas in red and areas with decreased disturbance in cyan..

These analyses demonstrated the time and cost utility of low cost imagery and simple analysis methods for detecting new trails, changes in trail use and possible shifts in immigrant activity. The results of these analyses were presented to the Border Patrol during an executive review in August and will be presented at "The 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment" in early October, 2005.

<u>Trail Feature Extraction:</u>

During this reporting period, the REASoN project team completed a significant SDSS demonstration project by finishing the detailed mapping of immigrant/smuggler trails along the 106 km (66 miles) San Diego Border Sector. The final immigrant/smuggler trail map was provided to the U.S. Border Patrol in Mid-June. The detailed trail map represents the first comprehensive trail assessment along any portion of the US-Mexico Border. The border region mapped extends from the international border northward for a distance of approximately 8 km (5 miles), which is the principal border interdiction region of the U.S. Border Patrol. The extent of trail networks within 8 km (5 mile) buffer north of the U.S.-Mexico Border far exceeds previous expectations. The trail map revealed is an incredible 7240 km (4500 miles) of immigrant/smuggler trails within the map's extent. The ability to produce this map using high-resolution imagery and minimal manpower resources confirms the utility and cost effectiveness of high resolution imagery as a trail mapping method.

The mapping project revealed that trail intensity was much greater than anticipated and varies widely along the border. In border areas where Mexican road networks approach from the south, border trail networks north of the border are more intense (Figure 3). As expected, extremely rugged or remote areas have less dense trail networks. The effects of terrain, border access from Mexico and the Border Patrol resources can be seen in the pattern of trail networks.

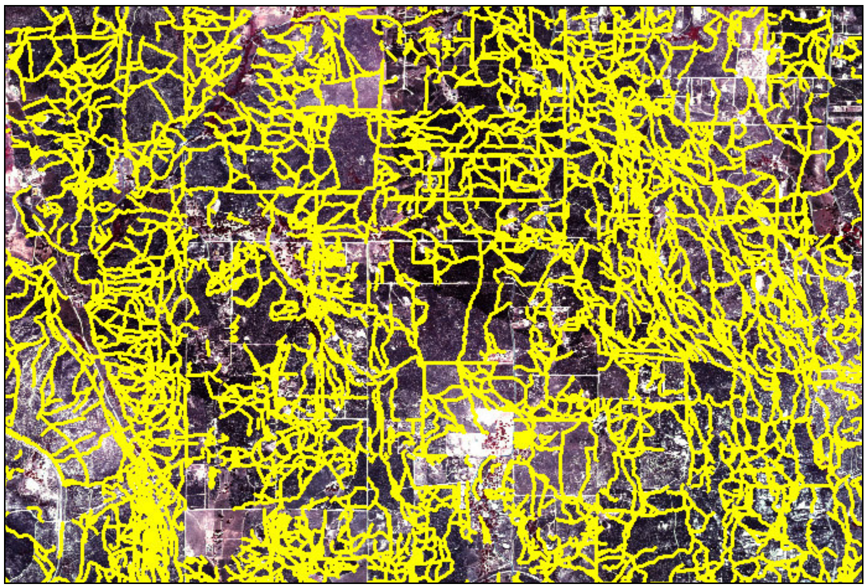


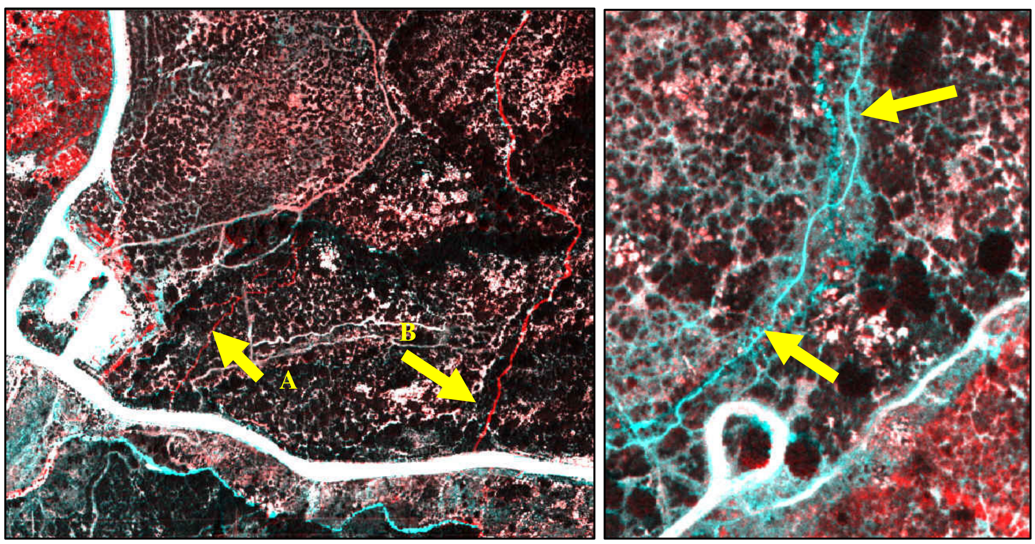
Figure 3. Map of main trails (yellow) near border on U.S. side showing extensive networking. Major east-west highway (Interstate 8) used to transport undocumented immigrants is only a few miles north of the top edge of map. This location is approximately two miles north of the border near Terra Del Sol, CA.

The utility of QuickBird panchromatic and pan-sharpened multispectral imagery (0.6 m spatial resolution) for mapping primary trails along the U.S./Mexico border was also evaluated. Pan-sharpened multispectral imagery was created using a resolution merge process which incorporated a principal components transformation of the data and cubic convolution resampling. The detail of features in the panchromatic and pan-sharpened multispectral imagery was comparable, and both products were found to have high utility for mapping primary trails within the border region. Trail maps created through visual interpretation of the QuickBird imagery generally matched those created through visual interpretation of much higher spatial resolution (0.15 m) imagery.

In addition, a spatial enhancement was found to substantially improve the discrimination of trails within the QuickBird imagery. The optimal spatial enhancement was the "5x5 Haze Reduction" convolution filter available in Leica's ERDAS Imagine.

Updating of Trail Network Maps:

SDSU personnel continue to develop and test procedures for semi-automated extraction of new trails and illegal crossing features using 0.15 m spatial resolution CIR imagery acquired in May 2004 and July 2005. Early this reporting period, the REASoN team digitally overlaid the red waveband from each multitemporal color infrared image to perform a semi-automated change detection analysis. The March 2005 red waveband was assigned to the red color plane, while the May 2004 red waveband was assigned to the green and blue color planes. In the resulting image (Figure 4), red indicated an increase in brightness between the two dates (e.g., new trail), while cyan indicated a decrease in brightness between the two dates (e.g., decreased trail use). The red lines in Figure 4a represent new trail features located in the Bell Valley region of the border. The cyan feature located at the bottom of the image in Figure 4a represents a normally barren, dry stream channel now filled with vegetation due to the record rainfall. Figure 4b shows an abandoned trail feature in cyan. The quality of the registration between these high resolution, multitemporal images enabled image analysts to discern detailed trail changes within the scene.



a. b.

Figure 4. Figure 4a show newly developed trails (red) detected using multi-temporal change detection methods. Figure 4b shows abandoned trail features masked by new vegetation.

During late May, the REASoN Project Team performed a field reconnaissance along the border to evaluate the presence or absence of trail features detected in Figure 4. Figure 4a shows a newly developed trail feature corresponding to feature A in Figure 4a. Figure 5b shows a newly created fire break corresponding to feature B in Figure 4a. The use of change detection methods holds promise for monitoring changes in regional patterns of smuggling and undocumented immigrant traffic.

(a)

(b)

Figure 5. Figure 5a shows a newly created trail in Bell Valley corresponding to feature A in Figure 4. Figure 5b shows a recently created fire break corresponding to feature B in Figure 4 located along the eastern edge of Bell Valley.

During August, the project team evaluated difference-images using the original 3-band imagery, PCA 1,2,3, PCA1, NDVI, IHS, and also a red band layerstack. Initial Feature Analyst runs on these difference transforms and the layerstack showed some promise in separating new trails from existing trails (Figure 6). Additional development and assessment is required and is on-going. An initial assessment of extraction methods are presented in Table 1.

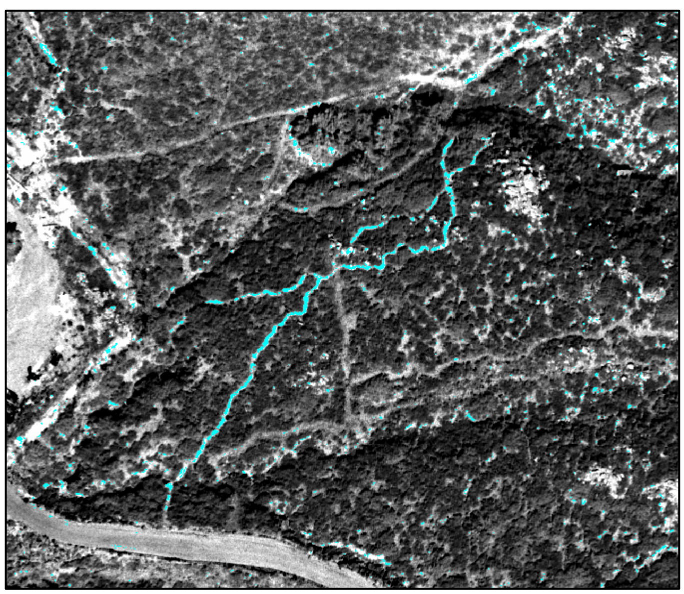


Figure 6. Graphic show cyan color trail feature extracted using PCA-1 difference image.

Table 1. Initial assessment of extraction methods

	Dataset Size	***Trail Extraction***	***Road Clutter***	***Rock/Bare Soil Clutter***	***Overall***
CIR	Large	Good	Low	Moderate	**B**
PCA 1,2,3	Large	Good	Low	Moderate	**B**
PCA 1	Small	Good	Low	Moderate	**A**
NDVI	Small	Segmented	High	High	**C**
Red Band	Small	Good	Low	Moderate	**A-**

Feature Analyst and eCognition software are being explored. Preliminary results suggest new trail features can be mapped reliably using semi-automated image processing procedures. The accuracy of resulting products has yet to be evaluated.

Expected or Realized Benefits (Metrics):

Our USPB partners have already disseminated image mosaics and trail network maps of the border tactical zone to agents within the San Diego sector. Vector maps showing the locations of border trails have been integrated into the U.S. Border Patrol's Spatial Decision Support System operated by the Command and Control Intelligence Coordination Center (CCICC) of the San Diego Sector Headquarters. The US Border Patrol is using this information to enhance active, passive, and tactical anti-terrorist and counter-smuggling detection activities. Trail maps have already begun to improve data collection for the U.S. Border Patrol's ENFORCE database by allowing accurate location of apprehensions and improved interpretation of law enforcement intelligence data. While specifics are confidential, successful interventions with smugglers have resulted from agents having access to both high resolution imagery and trail network maps. The border trails maps used in conjunction with the GIS real-time CCICC operations are serving as a model for Homeland Security development programs

Moderate Spatial Resolution Remote Sensing Focus Area

Supervised by Dr. Allen Hope

Vegetation Density/Condition Impacts Task

The Vegetation Density/Condition Impacts task is designed to assess changes in natural ecosystem condition along the US-Mexico border arising from human traffic and interdiction activities. The study is based on analyses of a time series of Landsat TM/ETM data.

Task Activities:

Natural Ecosystem Condition Assessment:

The original goal of this component of the study was to assess the impact of trail development on vegetation condition since the implementation of Operation Gatekeeper using the normalized difference vegetation index (NDVI) from TM/ETM+ imagery. The environmental effects from foot traffic and interdiction activities along the San Diego Border Sector remains an item of strong interest to the Border Patrol. Following a rigorous radiometric registration of the time series of four satellite images, we analyzed time differences in the NDVI and attempted to relate these differences to changes in trail densities derived from aerial photography. No relationships could be established.

Further study revealed that fire history and post-fire stage of vegetation recovery was the dominant cause of temporal differences in the NDVI. Consequently we modified our research strategy to control for post-fire stand age. The area along the 104 km (66 mile) length of the San Diego County-Mexico Border has an extensive fire history and is affected by the increase and decrease in vegetation due to fire and subsequent regrowth. Efforts were directed at examining temporal changes in NDVI in areas of similar fire history. Fire history maps for the border region were assembled and subset and used to identify regions of similar stand age so that we could repeat the analysis and control for stand age. Areas of mature stand age (no recent fire history) were identified along the border. To control for fire, the study focused on an area near Marron Valley for the analysis since it had not burned for over 20 years and showed evidence of new trail development between the two image dates. The three time periods were evaluated, 2002-1991, 1999-1991, and 1996-1991, to observe change within those periods. Again, comparison of NDVI differences over time relative to changes in trail density showed no relationship. Given this outcome, it was concluded that the relatively coarse spatial resolution of TM/ETM+ data may be contributing to the insensitivity of the NDVI to potential changes in vegetation condition.

In order to test this hypothesis, we extended the analysis further by using scanned high spatial resolution color infrared (CIR) photography collected in May, 2004 and July 2005 scanned to 0.15 m ground resolution elements. The image bands were radiometrically registered using an invariant feature, empirical line technique similar to the one implemented for the satellite data. The 0.15 data sets were used to generate 0.45 pixels (averaging) for the multi-resolution comparisons.

The extended analysis using scanned high spatial resolution color-infrared photography examined radiometrically registered CIR images and indicated that differences in solar geometry on the two dates appeared to cause significant illumination and reflectance differences on some hill slopes. However, conversion to the NDVI removed most of this effect. The identification of new trails was not impeded by the reduction in image resolution from 0.15 m to 0.45 m and, in some instances, the 0.45 m images yielded more well defined trails which may be a due to the better spatial co-registration at this resolution.

Current research efforts are now directed at comparing the NDVI between the two dates using sample polygons that have been selected to represent areas with and without new trails. These comparisons will be made using both spatial resolutions and we will also test a further level of aggregation (0.90 m).

Additional analysis of temporal differences in the NDVI using matched Fall-Spring image pairs of Landsat Enhanced Thematic Mapper Plus (ETM+) revealed that most of the areas of greatest change appear to be related to urban growth, though a few small clusters of high-change pixels appear in an area away from the urban landuse. Figure 7 displays the change in normalized difference vegetation index (NDVI) values showing increasingly negative NDVI change as cyan and increasingly positive NDVI change in pink. Black areas indicate recent fire scars. Cyan areas likely indicate drought effects while pink regions suggest urban vegetation growth. Additional research are higher spatial resolution is being considered. The effects of immigrant and smuggler induced fires is clearly evident in the NDVI image.

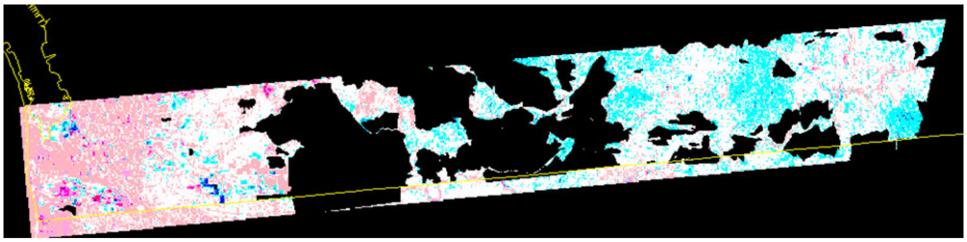


Figure 7. Map displaying NDVI change from Fall 1991 to Fall 2002. Increasingly negative NDVI change is colored cyan. Increasingly positive NDVI change is colored pink.

Attention is also being directed at providing data derived from the Landsat TM series as input to GIS models. Emphasis is on extracting vegetation data to support trafficability, visibility and fire risk modeling studies. Image-derived maps of vegetation conditions (e.g., density, structure, and moisture) are critical for determining trafficability for both undocumented immigrants and enforcement agents, visibility and concealment analyses and important components of assessing fire risk and potential landing sites for clandestine aircraft. Disturbance to vegetation and land cover in shrubland landscapes of the border region may indicate: 1) increased activity by undocumented immigrants, 2) impacts from USBP interdiction activities, or 3) development.

Expected or Realized Benefits (Metrics):

Image-derived maps of vegetation conditions (e.g., density, structure, and moisture) are critical for determining trafficability for both undocumented immigrants and enforcement agents, and important components of assessing fire risk and potential landing sites for clandestine aircraft. Disturbance to vegetation and land cover in shrubland landscapes of the border region may indicate: 1) increased activity by undocumented immigrants, 2) impacts from USBP interdiction activities, or 3) development. Historical satellite imagery has be used to examine the spatial patterns of vegetation disturbance, which along with time-series data, will be valuable for other models and applications within the tactical response zone (e.g., fire fuels, vegetation/habitat monitoring, trafficability modeling, etc.).

Geospatial Modeling and Analyses Focus Area

Supervised by Mr. John Kaiser

The geospatial modeling and analyses focus area contains six separate tasks each composed of multiple subtasks. Active tasks this reporting period included a clandestine airfield location prediction task and an aircraft radar fade analysis task.

Clandestine Airfield Location Prediction Modeling Task

The clandestine airfield location prediction task designed to assist in the prediction of clandestine airfield locations north of the U.S.-Mexico border through the combined use of remotely sensed imagery and GIS modeling. This analysis is designed to produce geospatial analysis tools for use by Border Patrol analysts to generate actionable intelligence for distribution and integration into in the Border Patrol SDSS.

Task Activities:

GIS and RS imagery collection:

Spotty progress continues to be made in the collection of needed data sets for the clandestine airfield modeling and analysis task. A notable success was the approval of a data access request submitted to NASA Headquarters (oescomm@mail.hq.nasa.gov) to obtain permission to acquire no-cost ASTER datasets for selected regions along the California – Mexico border. These imagery sets are used to assist in locating clandestine landing strips in regions adjoining the border. Initial assessment of the imagery indicates that the spatial and spectral resolution of these imagery sets are useful for detecting and monitoring clandestine landing locations.

Elevation data products from the Shuttle Radar Topographic Mission (SRTM) for the California and Arizona portions of the Mexican Border continue to be sought from the National Geospatial Data Agency (NGA) (formally NIMA). Border Patrol data requests continue to be denied by NGA. In May it was announced that selected Border Patrol personnel would be processed for NGA recognized security clearances to allow access to NGA data. Current expectations are for completed security background checks by early Fall 2005.

The project team contacted NASA representatives for assistance in acquiring high spatial resolution SRTM DEM data for San Diego Sector of the U.S and Mexico Border. NASA representatives have indicated they would pursue obtaining the data from NASA sources. High resolution elevation data remain essential to runway site detection. Data access is still pending.

Although contact has been made with USAF representatives at the National Guard Digital Mapping Center at Fort Gillem near Atlanta, GA to acquire a digital map of all known airfield locations within the US, the requested data products have not yet been received.

Data integration and pre-processing:

GIS data layers and remotely sensed imagery have been pre-processed to establish standard projections, scales and formats. Remotely sensed imagery and GIS layers have been projected into State Plane NAD 83 to match San Diego Sector formats. All GIS coverages and shapefile layers required as raster inputs for modeling have been converted to raster (grids) for use in model operations.

Model construction:

Preliminary landing field suitability model logic development has been completed. Several site suitability models were tested using existing data sets to determine optimal processing methods. Initial landing field prediction models suggested potential areas in eastern

San Diego county and western Imperial county. Figure 8 shows some of the geospatial layers employed in the model. Enhance digital elevation model (DEM) data and LIDAR reflectance data are needed to enhance location predictions. Initial model results are being compared against information gleaned from radar fade analyses of AMOC radar fade data. Clandestine landing sites detected using radar fade data suggest that the use of traditional airfields is rare. Secluded fields, remote roads and isolated hillside meadows are frequent landing sites. These elements are being factored into the prediction model. The principle study areas will focus on San Diego and Imperial Counties along the U.S. – Mexico Border. Additional model development using ArcGIS 9.0 Model builder, radar detection coverage, LIDAR elevation data and satellite imagery continue as new data arrives.

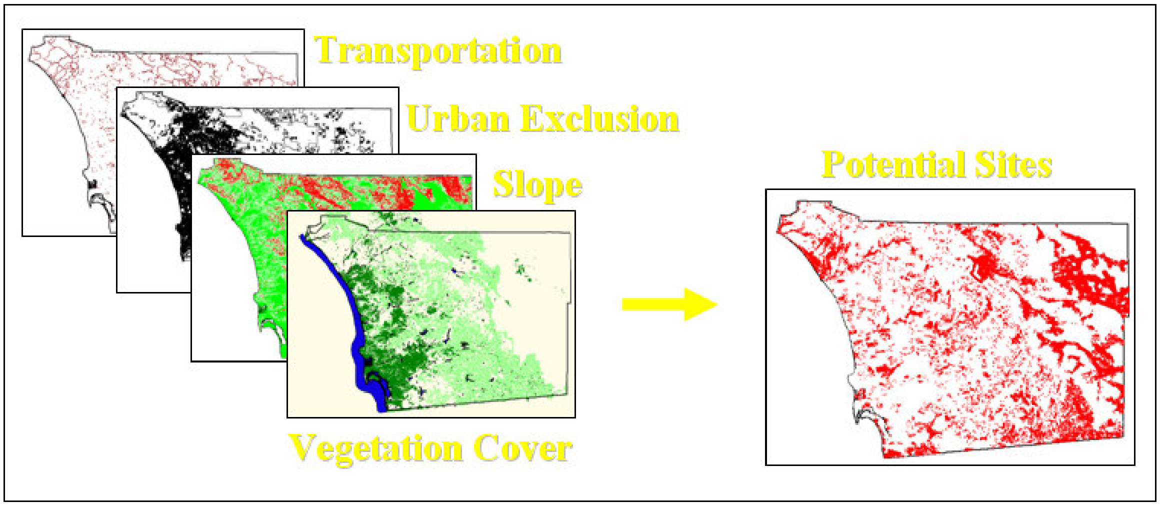


Figure 8. Generalized model for locating clandestine landing strips.

Identification of potential clandestine landing sites north of the U.S.-Mexico border is considered useful for counter smuggling operations by U.S. law enforcement agencies.

Technology transfer:

Results from the clandestine airfield suitability analyses have been briefed to San Diego Sector Border Patrol supervisors and intelligence staffs and AMOC personnel. The presentations generated substantial interest and discussion. Several suggestions were made on how to generate actionable intelligence information from these data using the projects analysis methods.

Surface radar reflectance analysis:

An exploratory collaboration with Dr. Rob Mellors (SDSU Department of Earth Sciences) to explore use of radar surface reflectance data to refine detection of land covers suitable for exploitation as landing sites was conducted. Surface roughness in conjunction with slope and vegetation cover were explored with radar fade data to locate potentially exploitable landing sites. Dr. Mellors examined radar reflectance and coherence images for several known landing sites to determine location and detection capabilities. Results presented to Border Patrol personnel in early May to evaluate initial results suggest limited benefit from this method. Spatial resolution of current radar image sets appear to coarse to be useful. Higher resolution airborne assets may hold significant promise. Such sources and methods are currently being applied in the Iraq theater of operations.

Aircraft RADAR Fade Analyses

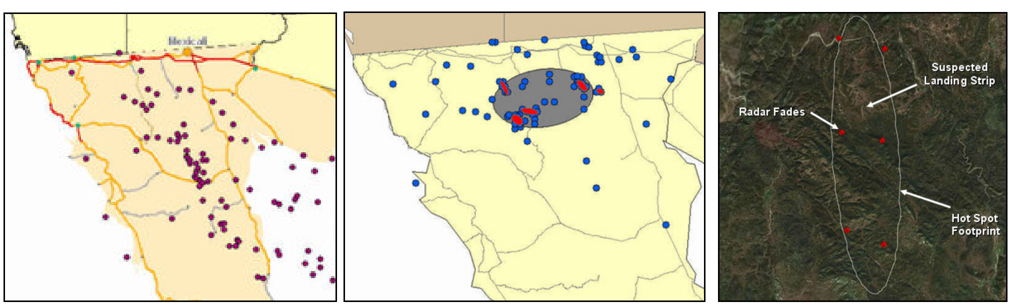
The aircraft radar fade analysis examines aircraft radar fades in conjunction with geospatial data and remotely sensed imagery to revealed patterns in aircraft smuggling activity useful for law enforcement countermeasures. This analysis is designed to produce geospatial analysis tools for use by Border Patrol analysts to generate actionable intelligence for distribution and integration into in the Border Patrol SDSS

Task Activities:

Air – Marine Operations Center (AMOC) data acquisition

Contact was established with the Air/Marine Operations Center (AMOC) at March AFB, CA through the U.S. Border Patrol to acquire border radar site location and radar footprint/visibility maps plus aircraft radar fade data from AMOC sources. Five years worth of radar fade data for areas in northern Baja California, Mexico were acquired. Radar fade data within the US was not present in the dataset.

Results of a preliminary analysis of radar fade data for areas in northern Baja California, Mexico were briefed to intelligence analysts at the Air Marine Operations Center (AMOC) at March AFB, CA in June, 2005. Analysis of the 2000 through 2004 data revealed useful patterns and trends in the radar fades to the AMOC analysts. Preliminary results show systematic patterns in the data and show fade clusters corresponding to clandestine airfields in northern Baja California, Mexico (Figure 9). Several common geospatial analysis methods were introduced to AMOC analysts who will employ them in future radar fade data analyses. Discussions about the data patterns and their implications continued with senior analysts following the briefing. Continued analysis of radar fade data shows promise for improving drug interdiction activities.



a. b. c.

Figure 9. Figure 9a shows typical radar detections. Figure 9b shows aircraft radar fades with standard deviational ellipse (gray) and hot spots (red) overlain. Figure 9c shows hot spot overlain over aerial imagery showing location of a clandestine landing strip.

Radar fade data within the US along the Mexican border has proven valuable in locating clandestine landing sites. Although radar site maps and radar footprint/visibility maps have yet to be received, analysis of AMOC data shows promise for improving drug interdiction activities.

Expected or Realized Benefits (Metrics):

The benefits derived from this study consist of obtaining and integrating information revealing the location of existing and suspected clandestine aircraft landing strips in the regions adjoining the San Diego Sector of the U.S. – Mexico border. This information, along with law enforcement intelligence information is being integrated into the U.S. Border Patrol's SDSS and into intelligence assessments. The US Border Patrol is using this information to enhance active, passive and tactical interdiction activities.

<u>Analyses of Interdiction Demographics Focus Area</u>

Supervised by Dr. John Weeks.

Origination – Destination Analysis Task

The interdiction demographics project will link and analyze characteristics of migrants apprehended at the border with the characteristics of the localities of origin in Mexico from whence they came. From these links, the project will identify factors pushing immigrants to U.S. and relate information about the individuals apprehended and their geographical paths to the border. The project will also analyze ESE satellite image-derived products in conjunction with USBP apprehension data by Border Patrol Sector in order to examine vulnerability to cross-border activity for the length of the U.S.-Mexico border. In a later phase, the research team will geocode locations of deaths along the border that are determined by the Medical Examiner to be undocumented immigrants. The team will use both airborne and satellite imagery to evaluate the risk characteristics of those places, in order to develop plans for mitigation.

Task Activities:

Apprehension Data:

During late May, the project team met with Border Patrol staff to review current analyses results, discuss current and future SDSS needs, and prioritize future research and analysis objectives. Additional border patrol personnel from the intelligence staff joined the review and discussions. Discussions focused on the contributions of the demographic studies to interpreting non-spatial intelligence data. The Border Patrol expressed strong interest in the results to date and confirmed that the project team had the correct focus in terms of the analysis objectives and products being produced.

The project team completed identifying the Border Patrol sectors at which people from each municipio in Mexico were arrested. Identification of such patterns allows our analysis to determine the likelihood of migrating to a specific border sector as a function of municipio of origin. The work continues on the analysis of factors predicting the origin of Mexican citizens arrested along the US-Mexico border. Progress continues to be made in analyzing the economic, social and political climate and how these variables 'push' migrants toward the United States. Using Principal Components Analysis, the project team identified three statistically significant factors that help explain the patterns of migration. These factors are Poverty, Infrastructure and Political Stability.

The project team has turned its attention to the sector along the border in which people from each area are arrested (Figure 10). As with the municipio data, individuals that were arrested multiple times in multiple sectors have been screened as we are interested in establishing one place of origin with one point of entry for each individual. All POE's in a certain community (e.g. Brownsville and San Diego) have been recoded to reflect the region of entry, not the individual crossing point. Preliminary analyses continue to indicate a strong tendency for people to go to the border sector that is the shortest distance from their place of origin.

Figure 10. Map showing sector along the border in which people from various Mexican states are arrested.

The project team completed compiling municipio of origin statistics from the ENFORCE 2003-2004 (San Diego Sector) data set. This is a key accomplishment for analysis of location of origin of illegal immigrants from Mexico (Figure 11).

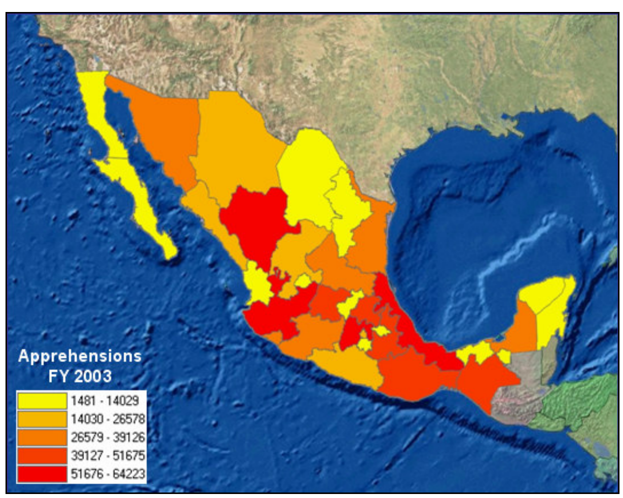


Figure 11. Map showing border apprehensions by Mexican state of origin.

In conjunction with the Data Mining Team, the project team established a procedure to generate apprehension statistics at municipio level. This allows the project team to determine how many apprehensions were from individual municipios which provides much finer demographic spatial resolution.

Using two gazetteers acquired from the National Geospatial Intelligence Agency (NGA) and the University of Columbia CIESIN, the project team was able to determine the origin (as municipio) of 64% of the records with presence of “city of birth” values. The process involved VBA scripting, database cleaning and re-formatting, spatial joining, GIS layers editing and variables matching. The EID datasets are now ready to be joined with socio-economics and census datasets from INEGI. When matching the EID apprehension data to the municipio reference information, it becomes possible to improve the determination of the distribution of apprehension patterns using socio-economical data from the municipios. The algorithm was tested on Baja California municipios and performed well.

The project team also made major progress in extracting demographic and economic data from the Instituto Nacional de Estadistica, Geografia e Informatica (INEGI) website for linking to U.S. border apprehensions data. By linking the characteristics of migrants apprehended at the border with information from their state and/or municipios of origin in Mexico and performing statistical analysis, we hope to identify factors which induce attempted immigration to the U.S.

The following variables are being collected and/or derived:

1) Total Population
2) Ratio of males 20-34 to females 20-34
3) Percent of children dead to women aged 35-39
4) Percent of total population older than 5 that speaks an Indian language
5) Percent of the 20-29 population that is illiterate
6) Percent of all males 25-29 who are employed
7) Percent of employed population that works in Agriculture or Mining
8) Percent of employed population that earns less than minimum wage
9) Percent of homes with piped water inside the home
10) Percent of homes connected to a sewer
11) Percent of homes with electricity inside the home
12) TFR
13) Percent of population 30-39 that lived in another country in 1995
14) Businesses per males 20-34
15) Employees per firm
16) Wages per employee
17) Gross product per firm

The demographics project team completed a data matrix at the state level (32 states) and is nearly finished with the complete data matrix for 26,600 municipios.

Expected or Realized Benefits (Metrics):

A major benefit of the project is the ability to model the predictors of migration from different regions of Mexico, to provide an underlying logic to the pattern of people being detained at various places along the border so that the migration consequences of changes in Mexico can be anticipated by the US Border Patrol. Project results will allow Border Patrol analysts to calculate the probabilities of people from different origins in Mexico being apprehended at each sector along the border, and also provide the mechanism for calculating differences in profiles of people who are apprehended at different sites along the border.

<u>Web-based GIS and Wireless GIS Communications Focus Area</u>
Supervised by Dr. Ming Tsou.

Wireless Mobile GIS Database Access Task

The major objective of this task is to test and implement mobile GIS components with wireless technologies for border security decision support systems. The goal is to provide border security officers with mobile GIS devices (Pocket PC) to access critical maps, imagery and geospatial information via secured wireless channels.

Task Activities:

Data warehousing and metadata

As part of the data warehousing research, there is a continual need for new data sets to simulate border patrol data so that data manipulation and query techniques can be evaluated. Dr. Tsou, the team leader for the Web-based GIS and Wireless project team, visited the San Diego Supercomputer Center (SDSC) to discuss opportunities to exchange and share regionally focused datasets between the REASON server and the GEON data server. Most GEON data are structured to serve data from global sources while the SDSU REASoN data server has more locally-oriented data sources. Since both Universities seeks to support community information needs, the sharing of data can be complementary.

During discussions, the REASoN team identified several potential areas of collaboration with SDSC including mobile GIS with a wireless scalable framework, future collaborative presentations at SDSC or SDSU and co-registering data sources, etc. The project team was also introduced to other Homeland Security research projects including E-911, BorderSafe, and RWBL projects. The project team is coordinating with the Supercomputer's GEON project team to demonstrate data sharing. Such sharing techniques are essential to homeland security data warehousing and retrieval of real time data services (i.e. weather, traffic, damage assessments, imagery, etc.).

As part of the data warehousing research, the project team has created a metadata list for Geography Department Archived GIS and Remote Sensing data. The new metadata list has been added into our REASoN project on-line metadata server. The following categories are created as metadata elements: live data and maps, downloadable data, offline data, static map images, other documents, applications, geographic services, and clearinghouses.

Dr. Tsou presented a paper at the ESRI International User Conference on July 28 describing an Internet-based Spatial Decision Support System (SDSS) using Real-Time Wireless Mobile GIS devices and also announced the establishment of the San Diego Emergency Response GIS data Portal (Figure 12). Additional development for the GIS data portal will focus on making the search function link to external databases (such as FGDC data clearing house and ESRI Geography Network).

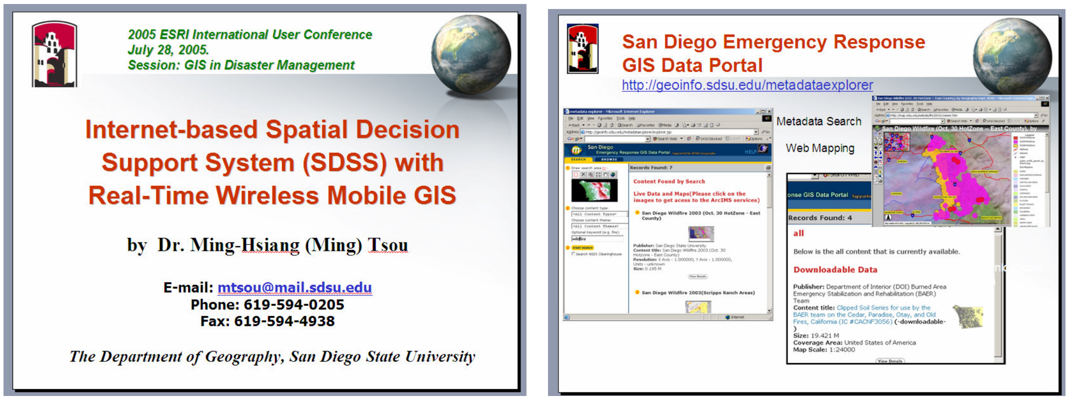


Figure 12. The 2005 ESRI International User Conference Presentaiton.

Data warehousing and metadata integration research continued with the research team finishing the design of SDSU Department GIS/RS data portal (Figure 13) with 360 metadata records in GIS and RS. These development efforts for the GIS data portal will focus on making the search function able to link to external databases (such as FGDC data clearing house and ESRI Geography Network). The collections of SDSU Geography Department metadata will be integrated within the San Diego Emergency Response GIS Data Portal. Similar connectivity capabilities will be required by the Border Patrol's SDSS.

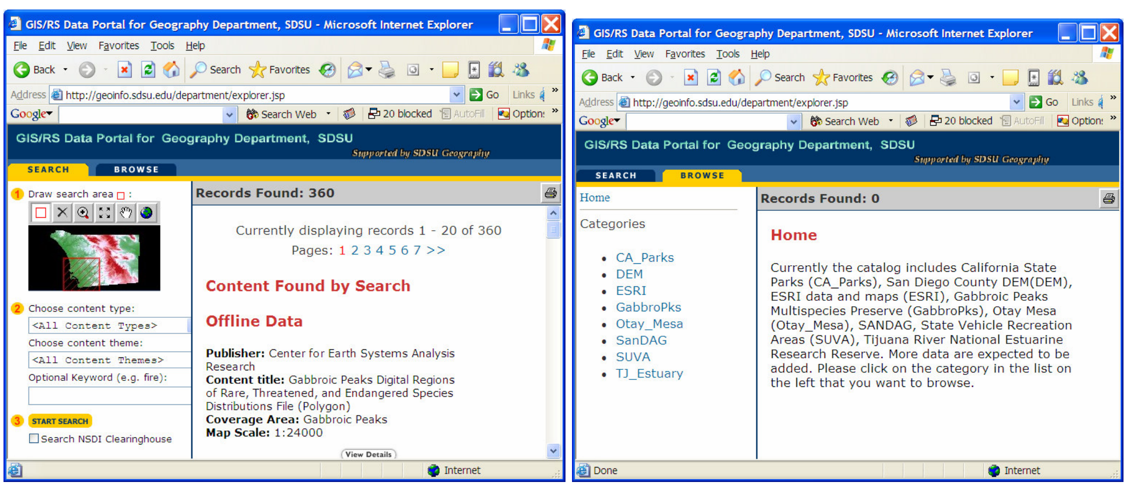


Figure 13. The Data Archived GIS portal for SDSU Geography Department.

Web-based mapping/spatial query

The research team continued to focus on how to customize ArcIMS viewers to provide online mapping and analysis functionalities via secured communication channels. Such functionality is necessary for Border Patrol sectors to exchange information or to query information from intelligence processing centers such as the San Diego Sector CCICC. These viewers will become the frameworks for further spatial data processing and decision making platforms.

A major emphasis for the ArcIMS viewers is user interface design. The project team is exploring the look and functional arrangements of various interface designs to effectively display measurements, layers, update modes, and map styles. Other interface elements being explored include background color, transparent mode, map image formats, and ease of use in conducting mapping tasks.

The project team created sample websites (Figure 14) for demonstrating the capability of Web-based mapping for the REASoN project including 3-D imagery. The URL for this new website is **http://geoinfo.sdsu.edu:8081/border** The website includes both the mobile GIS introduction and Internet mapping showcases.

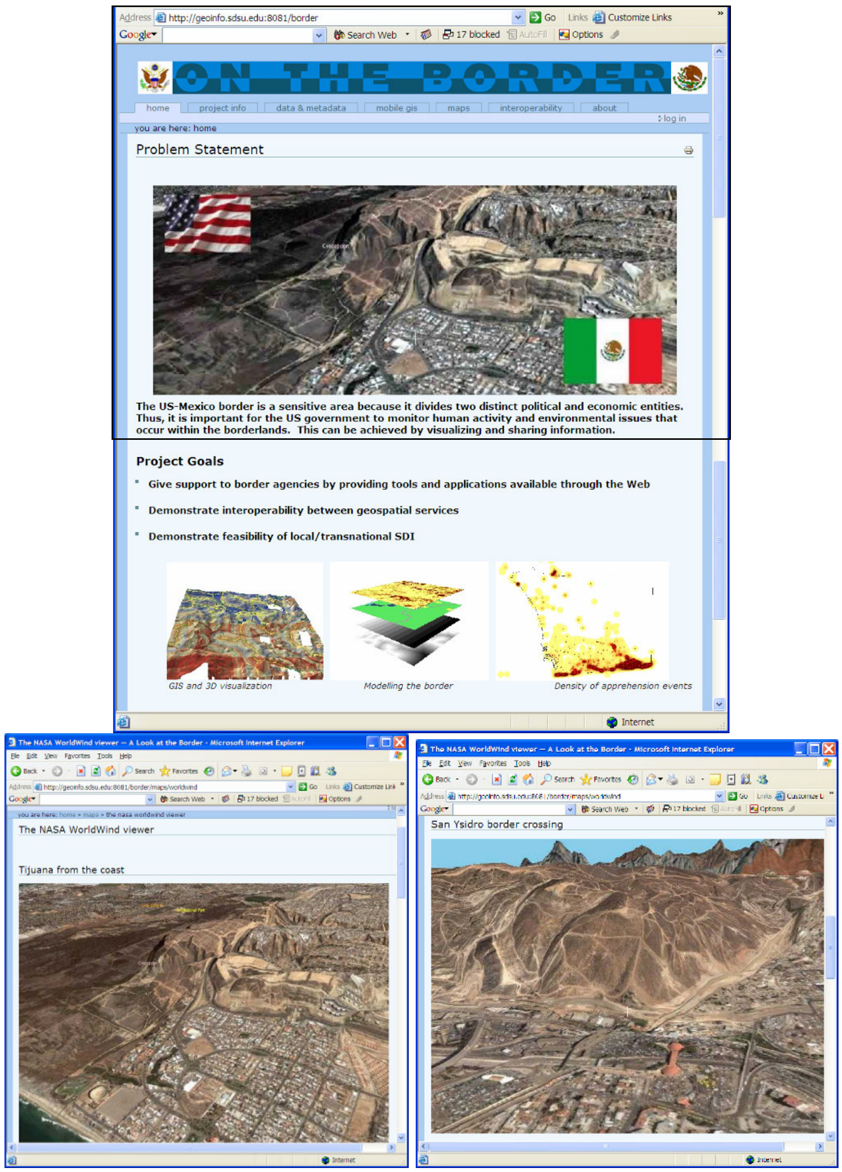


Figure 14. The show case web pages of 3D mapping and visualization.

One of the major challenges facing the border patrol SDSS is the speed at which law enforcement sensitive data can be transmitted to agents in the field over encrypted communications links. To address this issue, the research team compared the performance between secured Internet communication (HTTPS) versus un-protected Internet communication protocol (HTTP) for Web-based mapping applications. For comparison purpose, the project team created two identical ArcIMS Web pages. One is for regular Web access (HTTP) and another is built by secured transfer protocol (HTTS) with public/private key authentication. The project team then created several Javascript codes to measure the performance of the two ArcIMS Web applications and record the time (seconds) needed for different mapping tasks (Zoom-in, Zoom-out, query, layer operations, etc.)

The project team conducted the tests using two different computers. One was a typical HOME computer via ADSL connection speed (154Kbps). The other computer was a WORK PLACE computer using regular Fast Ethernet connection speed (100Mps). The tests results are presented in Table 2.

Table 2. Performance testing between secured vs non-secured Web Mapping.

HOME machine Test Time units: **second**

Mapping Tasks	**https (Secured communication)**	**http (regular communication)**
Initialization	28 (including password inputting)	13
Zooming in (average for 10 tries)	1.347 (initial zooming takes more time than subsequent zooming)	0.919
Zooming out (average for 10 tries)	1.117 (the more details currently displayed, the more time spent)	0.882
Zooming to full extent	0.972	0.812
Panning	1.883	2.524
Identify (average for 10 tries)	2.891	2.875
Query	2.780 (use same query)	1.890
Layer operation (remove)	2.125	2.063
Layer operation (activate)	2.187	2.031
Layer operation (add)	2.891	2.609

WORK PLACE machine Test
time units: **second**

	https	http
Initialization	10(including password inputting)	6
Zooming in (average for 10 tries)	0.609(initial zooming takes more time than subsequent zooming)	0.594
Zooming out (average for 10 tries)	1.390(the more details currently displayed, the more time spent)	1.281
Zooming to full extent	1.063	0.843
Panning	3.578 (slow because the lag of remote desktop connection)	3.125
Identify (average for 10 tries)	2.735	2.718
Query	1.562(use same query)	2.603
Layer operation (remove)	1.187	1.516
Layer operation (activate)	1.188	1.531
Layer operation (add)	1.484	1.984

Generally, the response time for the HTTPS case is slightly slower than HTTP. The initialization stage has a significant difference. One exception is the layer operations from work place machines seems run more quickly with https than with http which is against the general rule. The SDSU research team continues to compare the performance of Internet communication protocols (HTTP) for Web-based mapping applications.

Recently, the project team began to explore a new development in Web-based mapping technology, called "Google Earth" (Figure 15), http://earth.google.com/. The performance of this system is much faster than traditional web-based mapping tools. Research team members are considering adoption of this new technology for SDSS Web-based mapping tools. The project team has conduct an initial comparison of the differences between the new software

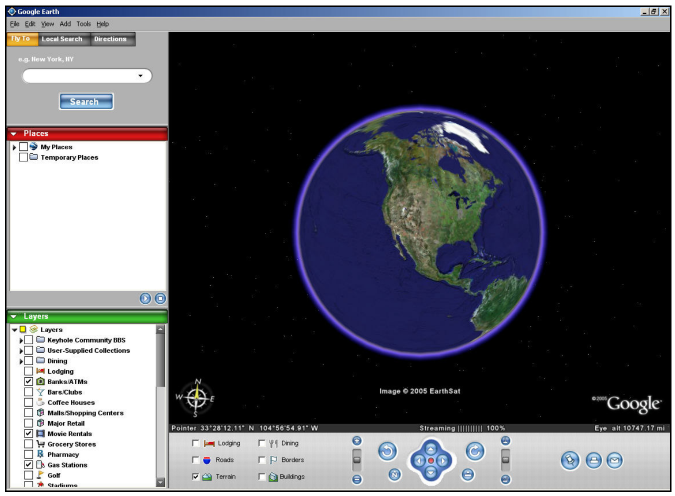


Figure 15. Google Earth Interface. (New potential for Web-based mapping).

package (Google Earth) and the ArcIMS to document strengths and weakness for SDSS applications. Results of the initial assessment are listed below.

Advantages of Google Maps and Google Earth Products

- Provide free GIS vector and satellite image data;
- Simple and easy to customize;
- Provide platform to integrate various data;
- Many people are working on these applications now (have a good community support from other users);
- Open API;
- Good cartographic symbols design;
- 3D visualization and excellent performance.

Disadvantage of Google Products:

- Software developer will require significant knowledge in Google's APIs
- Do not have common cartographic tools (like layer management, search, identifying, measure, selecting and other tools);
- Lack of spatial analysis functions (buffering, spatial query, etc).

- Need a data converter to access Shapefile data sets.

ArcIMS advantages:

- Most GIS developers are already familiar with the software,
- Can provide advanced GIS and cartographic tools, such as layer management, search, identifying, measure, selecting and other cartographic display tools.
- Use Shapefile directly.

ArcIMS disadvantages:

- Poor performance;
- Relatively hard to customize (Less freedom to make changes to both interface and functions);
- Inconvenient management (through IMS Author, Administrator, Designer and difficult to enter new data);
- Poor cartographic symbols design;
- Not easy to find reusable customizing codes (poor documentation and example);

The project team conducted several application experiments using the new Google Earth Web-based mapping technology, using Google Map API to display simulated border apprehensions along San Diego Sector of the U.S.-Mexico border (Figure 16).

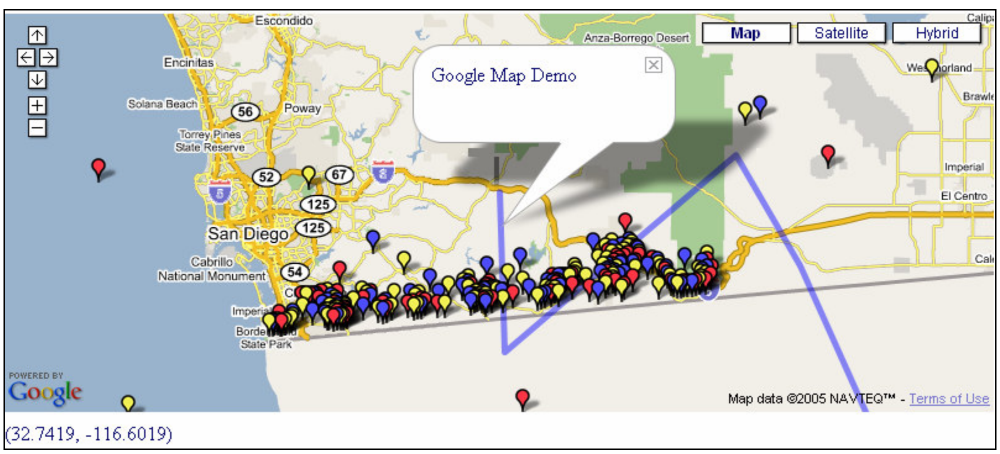


Figure 16. Simulated border apprehensions shown over a thematic map.

The REASoN project team observed that Google map has been used in many web mapping applications following its public release. Its simple yet powerful mapping interface offers detailed street-level map as well as high resolution satellite images service functionality suitable for SDSS applications (Figure 17). A demo showing some of the interactive characteristics of an integrated web site with web based mapping an query is found at **http://geoinfo.sdsu.edu/reasondemo/**. The Google map is embedded into common web page.

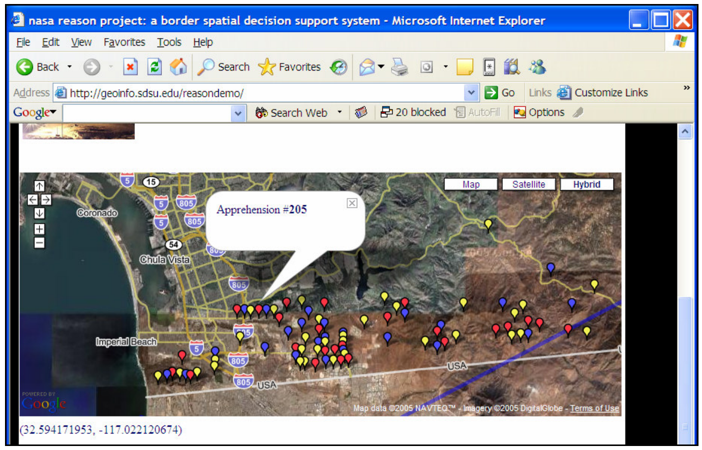


Figure 17. A screen capture of an integrated Google Map with REASoN Data

Publications and Presentations

In September, Dr. Tsou wrote an article about the recent changes in Internet GIS. The paper can be read at the following URL:
http://www.gisdevelopment.net/technology/gis/techgis_002.htm

This paper introduced several new technologies for Web-based mapping: AJAX (Asynchronous JavaScript and XML) and image tiling techniques for Web-based 3D visualization. The following paragraph is cited from the paper directly.

“Traditional Internet GIS applications and Web-based mapping tools always suffer from the slow response and the lack of high resolution images because of the limitation of image data sizes and the client/server communications. The two new technologies (AJAX and image tiling) can improve the performance and repose times of Internet GIS application significantly.”

Dr Tsou observed that the two new technologies have co-existed for a long while before Year 2005. However, the combination of the two technologies was not seen until the early 2005. The [maps.search.ch] and [maps.google.com] internet sites are the two early examples of Internet GIS applications which adopt both AJAX and Tiling techniques together. Amazon's [maps.a9.com] is also a good example of AJAX applications with a very interesting "Street Block View" function. Microsoft also has its own AJAX map application [virtualearth.msn.com]. AJAX is not a single technique but a combination of multiple web techniques for creating fast response, interactive web applications. AJAX can send user's requests to the web server to retrieve only the data needed by the request (Figure 18). Therefore, the total amount of images or data interchanged between the client browser and web server will be reduced significantly. For example, if users need to zoom-in to a new map area in a Web map browser, the server will not need to reprocess the whole map page content but only to re-send the smaller area of map requested by the user. By using Simple Object Access Protocol (SOAP), JavaScript, or similar XML-based web service protocols, AJAX applications users can have very responsive actions. This is critical to border patrol SDSS applications.

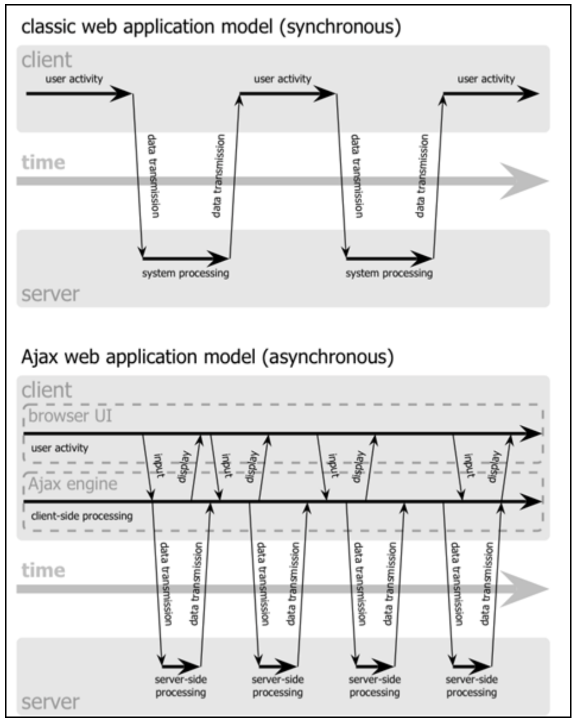


Figure 18. The synchronous interaction pattern of a traditional web application (top) compared with the asynchronous pattern of an Ajax application (bottom). (This image and caption are cited from the on-line Adaptive Path paper: **[Ajax: A New Approach to Web Applications](http://www.adaptivepath.com/publications/essays/archives/000385.php), by [Jesse James Garrett](http://www.adaptivepath.com/publications/essays/archives/000385.php)** (original URL: http://www.adaptivepath.com/publications/essays/archives/000385.php)

The second major technique used in the Internet GIS is the Image Tiling for Web-based 3D visualization. The introduction of tiled images is to improve the application performance by allowing the application to process an image region within a number of tiles without bringing the entire image into computer memory. Many early Web image applications have adopted this method for a while. In early 2005, several Internet GIS applications (such as Google Earth (http://earth.google.com) and GeoFusion (http://www.geofusion.com/) started to improve the image tiling techniques for their 3D visualization tools and created an interactive, fast-performance virtual reality in a digital earth form. Users can overlay aerial and satellite images with digital elevation model (DEM) to visualize the 3D spatial information.

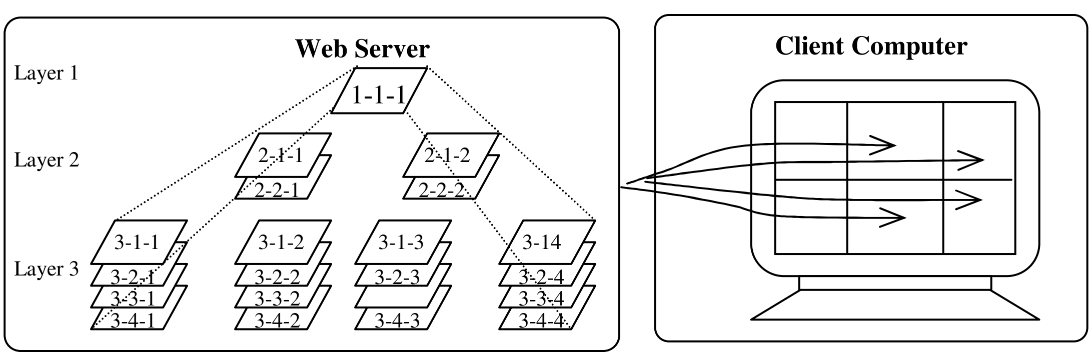


Figure 19. A Three-layer Tile-based Pyramidal Image Model

Research team graduate students created a highly informative poster for display in the Map Gallery of the ESRI User conference. The conference was attended by over 10,000 GIs and remote sensing specialist from over 100 countries. The poster introduced the basic idea of wireless mobile GIS and described the NASA sponsored "*Border Security Decision Support System Driven by Remotely Sensed Data Inputs*" project (Figure 20).

Figure 20. The Project Poster in the Map Gallery of 2005 ESRI International User Conference.

Project team members also attended the NASA SPG meeting at Double Tree Hotel (San Diego), June 15th. The discussion focused on five selected standards: OPeN-DAP, GeoTIFF, HDF5, NetCDF4, WMS.

Representatives from the project team also attended the UCGIS 2005 Summer Conference (Jackson Hole, WY) June 29th - July 2nd. A presentation and a paper with the following title: "Spatial Knowledge Discovery through an Integration of Visual Data Exploration with Data Mining" was presented at the conference on June 30th.

Expected or Realized Benefits (Metrics):

Development and integration of a near real time spatial decision support system prototype which combines real time GPS tracking, GIS Web portals, online mapping services, and real time in-field agent data update will help optimize tactical and strategic border management tasks. Wireless Mobile GIS development and the ability to demonstrate new wireless technologies and the real-time data dissemination functions are new technologies and architectures that can be transferred to the Border Security Decision support system and provide valuable experiences and testing results for the future adoption by the U.S. Border Patrol agency. The data and wireless security studies will also provide guidance for the Border Patrol agents on how to protect their data systems and communication channels more effectively.

Spatial Decision Support Analytical Tool Research and Data Mining Focus Area

Supervised by Dr. Piotr Jankowski.

Spatial Decision Support System Architecture Task

The SDSS architecture task involves developing Border Patrol SDSS analyses needs, evaluating the suitability of decision support methods, and developing prototype software component specifications for SDSS implementation.

Spatial Data Mining:

At the beginning of the reporting period, the project team conducted a technical interchange meeting with the San Diego Sector Border Patrol technical staff to identify and transfer analyses results, data mining strategies and algorithms, and to discuss future data mining analysis developments. Based on the discussions, the project team focused on developing a work plan for 2005. The work plan included the following tasks:

1. Review previous data analysis steps and create a list of analytical procedures that have been used thus far including data preprocessing, descriptive statistics, origin analysis, event role analysis, movement simulation, recidivist analysis, and disposition analysis. Document of each procedure including data input requirements, method/algorithm, and data output interpretation guidelines. These activities will aid in transferring analysis methods to the Border Patrol.
2. Reformulate research hypotheses in light of the past analyses results.
3. Verify the hypotheses using the full 2003-04 data set. Document computational challenges and limits.
4. Implement a point summarization algorithm in ArcGIS.
5. Combine the 2003-04 dataset with socio-demographic data from Mexico.
6. Review point data and spatial statistics analysis methods to find additional analysis methods; review other research analyses on space-time activities, criminal analysis.
7. Use the “Rough Sets” methodology to develop a predicative spatio-temporal model of border penetration by illegal immigrants.

The Border Patrol expressed a strong interest in implementing REASoN project data mining algorithms as operational tools. Once operationally tested and validated by the San Diego Sector, these tools will be implemented in other Border Patrol sectors around the US.

By mid-summer, the project team had completed the following activities:

Review of previous analysis works

The analysis document records twenty major analysis tasks. For each analysis task, the document provides a detailed description regarding its purpose, the required data inputs, the methodology, tools used, examples, output products, and related analysis.

Generation of event based map

The project team successfully implemented a VBA program to produce an event map which includes the information of apprehension number, number of participants, principal origin, and the index of similarity of participants’ origin to principal’s origin.

Updated EID data dictionary

Deleted unnecessary variables and added new derived variables descriptions. Reproduced the shapefile for the 2002-2004 EID data. The team dramatically reduced the data size from 1.2 G to 114 MB.

Review of point analysis techniques and tools

Most of the team's previous data analyses were based on point pattern analysis. The team conducted a literature review of research on this issue. Team members developed a pseudocode for Spatial Summarization of Point Distribution algorithm.

Tests on GeoStatistical tools in ArcGIS

Major tools tested are: normal QQ plot; general QQ plot; trend analysis; GeoStatistical wizard; creation of subsets.

Tests on Weka Knowledge Explorer methods

Tools tested include: clustering, J48 classification, Knowledge Explorer UI. Further implementation will show whether they are useful to discovery patterns.

Reformulation of hypotheses and research questions

The project team is reviewing proposed methods for addressing each questions and proposing a suitable analysis method.

Rough Sets methodology

The team reviewed selected articles about Rough Sets methodology for data classification rules. The team investigated whether Rough Sets might be applicable to the automated discovery of patterns in the apprehension database. The automated pattern discovery may be applicable to operational decision making, especially when real or near-real time data from various sensors are used.

The project team also acquired the latest version of CommonGIS, with spatio/temporal analysis capabilities. The software has been installed, customized for the specific needs and preliminary analysis performed on a sample dataset.

The data mining project team revised the EID analyses including descriptive analysis, origin analysis, event role analysis, density analysis, and hypothesis formulation. Figure 21 demonstrates the results of temporal analysis of illegal immigration by Mexican state origin based on quarterly intervals. The origin states with more than the quarterly mean are represented by different shades of blue and bars scaled proportionally to the number immigrants above the mean.

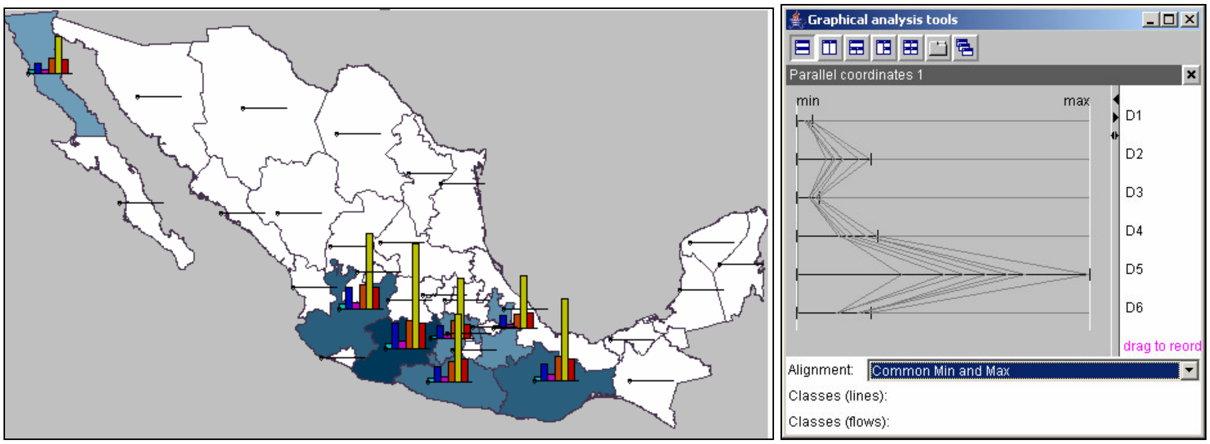


Figure 21. Map showing quarterly flow of immigrants (bar graphs) from southern Mexican states

The Data Mining project team met with the Demographics Analysis team to discuss expansion of the demographic analysis and Mexican push factors analysis. It was decided that the Data Mining team would approach the problem from different perspective. As a result, an algorithm was created using the VB programming language that identifies the Mexican state from which each apprehension subject comes from. The project team downloaded municipio spatial data and gazetteer files from various Mexican websites. Matching this reference information sets with EID apprehension data improves the quality of information about the municipios from which immigrants come.

The project team then established a procedure to generate apprehension statistics at municipio level. This allows the project team to determine how many apprehensions were from individual municipios which provides much finer demographic spatial resolution. When matching the EID apprehension data to the municipio reference information, it becomes possible to improve the determination of the distribution of apprehension patterns using socio-economical data from the municipios. The algorithm was tested on Baja California municipios and performed well. Based on this, it will be possible to show the distribution of undocumented immigration among municipios and improve the explanation of the migration patterns using socio-economic data.

The project team also created several additional predictor datasets to expand a model for predicting geographic patterns of illegal immigration across the border. For the San Diego County sector, the following predictive layers have been derived and reclassified in terms of enhancing/decreasing difficulty to cross the border: slope (from 10 m DEM), land use and vegetation cover (SANDAG 2000), density of trails and roads (digitized from SDSU HR imagery), density of types of fences (BP shapefile), weather average conditions and temperatures.

Most recently the project team has focused on developing a segmentation of the border into homogeneous segments representing the difficulty of crossing the border by the illegal immigrants. The difficulty of crossing the border is being modeled as a weighted average of the following spatial variables: climate, border fences, landuse, major roads, slope, density of trails, vegetation, enforcement of border control, and intensity of smuggling along the San Diego county section of the US-Mexico border. Weights representing the relative importance of spatial variables were obtained from a Border Patrol expert. The result of running the spatial weighted average model is a score assigned to each raster cell of a grid representing a 0.5 mile-wide strip along the US-Mexico border within San Diego County.

In addition, the project team is working on the integration of the Google Earth map service with apprehension data and analysis results to improve 3D visualization and interpretation. The project team has implemented several vector and raster integration modules with the Google Earth map service to display border apprehension data and analysis results to improve information display and interpretation (Figure 22).

Figure 22. Picture showing density of apprehensions overlain on satellite image along San Diego Border Sector using Google Earth map service.

Expected or Realized Benefits (Metrics):

The benefits from this research are methodological and practical. The methodological benefits include the successful application of advanced cartographic visualization tools combined with data classification techniques to a large-size geographic datasets. The practical benefits include the detection of patterns of movement of illegal immigrants from Mexico into the US along the San Diego County section of the border. Results are expected to extend our knowledge on how to effectively use exploratory data visualization methods combined with spatial data mining techniques to detect and exploit spatio-temporal patterns derived from large USBP apprehension datasets. This should improve intelligence analyses and antiterrorist field operations.

<u>SEEDS Standard Process Working Group Participation Focus Area</u>
Supervised by Dr. Ming Tsou.

SEEDS Standards and Interoperability Task

The major objective of this task is to participate in Strategic Evolution of Earth Science Enterprise Data Systems (SEEDS) activities and engage with other REASoN projects and ESE stakeholders to facilitate the data sharing, software reuse, and system interoperability.

SEEDS (ESDSWG) Meeting Attendance

Two REASoN team members attended and participated in the ESIP Federation meeting held on June 14-16, 2005 in San Diego at the Doubletree Hotel Mission Valley at Hazard Center. Due to scheduling issues, the ESDSWG (the SEEDS groups) was not an official workshop in conjunction with the ESIP conference After the meeting, the SDSU research team met on July 6th to review and discuss meeting items.

The date of the next ESDSWG meeting has been finalized on October 25, 26, and 27. Dr. Tsou will attend the 4th ESDSWG meeting on October 25, 26, and 27 in Washington D.C. A Poster (A Look at the Border) will be represented in the poster session at the meeting. The SPG group is currently working on the adoption of OGC's WMS specification and potential HDF data format. Dr. Tsou continues to participate in the weekly SPG staff telecom meeting and monthly SPG all members meeting, and the co-chair meeting each month.

Expected or Realized Benefits (Metrics):

The major objective of this task through participation in the Earth Science Data System Working Group (ESDSWG) activities is to engage with other REASoN project personnel and ESE stakeholders to facilitate REASoN data sharing, software reuse, and system interoperability. The recommended standards from the SPG and other working groups will help all REASoN projects to share their data and systems among each other and facilitate the communications and interoperability between the NASA funded projects and data systems. The twice-yearly meetings create more communication opportunities and the experiences exchanges among REASoN projects.

Publications, Proceedings and Presentations from SDSU-REASoN Projects

Presentations:

Tsou, M.H. (2005). Internet-Based Spatial Decision Support System with Real-Time Wireless Mobile GIS. In 2005 ESRI International User Conference, July 25–29, 2005
San Diego, California, (Abstract URL:
http://gis.esri.com/library/userconf/proc05/abstracts/a1115.html)

Publications:

Tsou, M.H., Guo, L., and Howser, T. (accepted 2005). A Web-based Java Framework for Cross-Platform Mobile GIS and Remote Sensing Applications. *GIScience & Remote Sensing*.

Tsou, M.H. and Sun, C.H. (accepted, in press 2006). Mobile GIServices Applications in Disaster Management, Book chapter in *Dynamic and Mobile GIS: Investigating Change in Space and Time*. (edited by Drummond, J, Billen, R., Forrest, D. and Joao, Ed. 2006. published by Taylor & Francis. (Innovations in GIS book series).

Tsou, M.H. (In Press 2005). Bridging the Gap: Connecting Internet-based Spatial Decision Support Systems to the Field-based Personnel with Real time Wireless Mobile GIS applications. Book chapter in *Collaborative Geographic Information Systems* (Edited by Shivanand Balram and Suzana Dragicevic). Idea Group, Inc.

Educational Sponsorship:

The SDSU-NASA REASoN program is assisting the research of eight graduate students during 2005. Four additional graduate students have or are completing Graduate theses based upon REASoN research. Research results have been incorporated into graduate and undergraduate GIS and remote sensing courses.